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VECTOR NETWORK ANALYZER

Abstract. *The article is devoted to vector network analyzer (VNA). Accurate, inexpensive instruments are widely used in the modern measurement. In the course of work, the advantages and disadvantages of the new device were identified, the principle of operation of the device, some experimental results are given. This article covers some of the basics that will help everyone understand the structure and operation of the VNA. .*

Keywords: *measurement, high frequency, radiofrequency measurement, vector network analyzer.*

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ВЕКТОРНЫЕ АНАЛИЗАТОРЫ ЦЕПЕЙ

Аннотация. *Статья посвящена векторным анализаторам цепей (ВАЦ). Точные, недорогие приборы, широко используемые в современных измерениях. В процессе работы были выявлены достоинства и недостатки нового устройства, рассмотрен принцип работы. Также в статье описан принцип работы прибора, приведены некоторые экспериментальные результаты. В* *статье рассмотрены некоторые основы, которые помогут понять устройство и принцип работы ВАЦ каждому.*

Ключевые слова: *измерения, высокочастотный, радиочастотные измерения, векторный анализатор цепей.*

Introduction:

The Vector Network Analyzer (VNA) is a modern piece of test gear that was once relegated to specialized measurements.

Previously, this tool was large, expensive, and did not provide a reasonable performance advantage to justify the increased cost. Older VNA was often delicate. As technology has advanced and test frequencies increased, however, the VNA paradigm has drastically changed. The measurement flexibility increased as did the ease of calibration.

The new VNA also allows new measurement possibilities such as accurate correction for cable losses or antenna input impedance over frequency. The latest generation VNAs can even accurately model nonlinear performance to predict changes in DUT (device under test) load or source impedances, something the legacy hardware could never do.

Legacy hardware cannot measure phase data and, therefore, cannot remove the effects of changes in cabling or load characteristics. In this paper, the efficacy of the proposed VNA is demonstrated via numerical simulations and experimental measurements.

The paper will then show that the VNA offers a low-cost alternative that improves reliability and accuracy, especially as our operating frequencies continue to increase.

The VNA is no longer an option. It is a necessary tool in modern measurement. This paper will discuss the disadvantages and differences between a vector network analyzer (VNA) and a scalar network analyzer (SNA).

VNA – the basic

Everyone who at least once heard about this device has always asked me the question "What kind of device is this?" To make the information easier to perceive - let's start with the very basics.

A vector network analyzer is a device that measures the characteristics of the signal flow through the so-called device under test and the characteristics of the signal that has been reflected from its ports. These very characteristics are called S-parameters. The S-parameter has indices that depend on the number of ports and the direction of the signal. Each such parameter carries information about the amplitude-frequency characteristic (AFC) and the Phase-frequency characteristic (PFC).

This knowledge will be enough to understand how measurements are made using the Vector Network Analyzer.

Measurement

Measurements on modern vector network analyzers are performed as follows: A sinusoidal signal is applied to the input of the device under test, and then two signals are measured: the one that was reflected and the one that passed through the device under test. Both of these signals will differ from test one in-phase and amplitude.

In the process of studying the articles, we came across two types of network analyzers – a scalar network analyzer and a vector network analyzer. The difference, in simple terms, is that the Scalar Network Analyzer can only measure amplitude, while the Vector Network Analyzer can measure both amplitude and phase.

For clarity, Figure 1 shows a simplified block diagram of a vector network analyzer. In this figure, the vector analyzer works in the forward direction, that is, the S-parameter has indices S21. A reference (with known characteristics) sinusoidal signal is applied to the DUT. The signal characteristics will change at the output of the device under test. Next, the amplitude and phase detector will be involved, it determines how much the known value of the amplitude and phase has changed. This will determine the characteristics of the device under test at one frequency. To measure the response over a given frequency range, the vector network analyzer will repeatedly change the frequency within the given range.

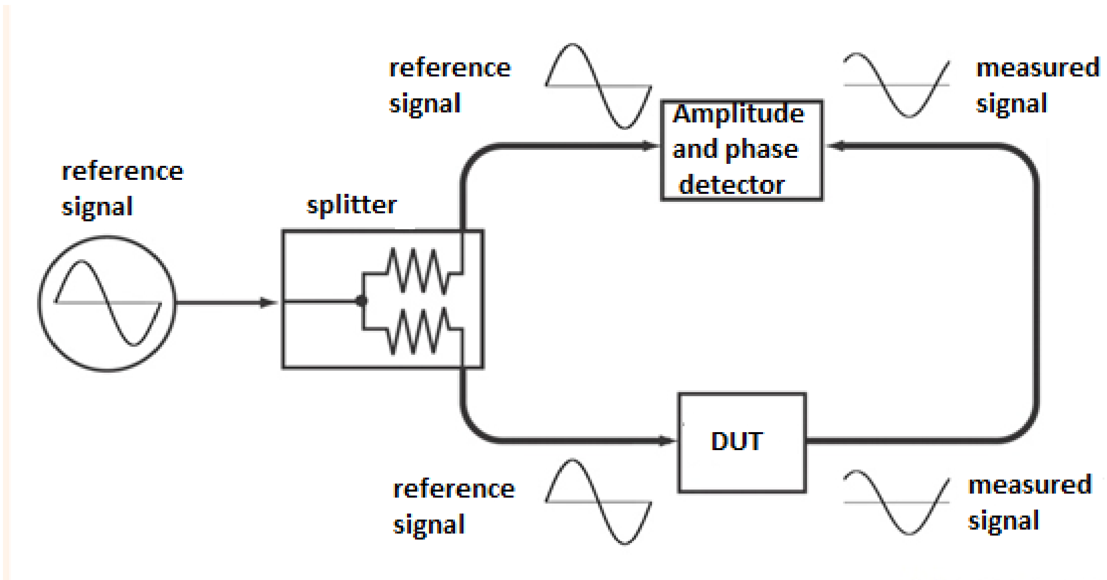

Fig. 1. – Vector Network Analyzer.

Application area

Vector network analyzers have found very widespread use in our time. Most often, they are used to solve three main tasks:

1. Measurement of passive and active characteristics of radio devices;
2. Measuring the absorption and reflection of radio waves;
3. Measurements in the medical, chemical, and food industries.

Using a vector network analyzer, you can even measure grain moisture and many other amazing parameters that at first glance are not related to radio measurements.

Types of network analyzers.

Previously, these were large and expensive devices. For example, in Figure 2, a four-port model of a vector network analyzer – VectorStar ME7838 is presented with a set of various cables and adapters that are used to connect to the measurement object.

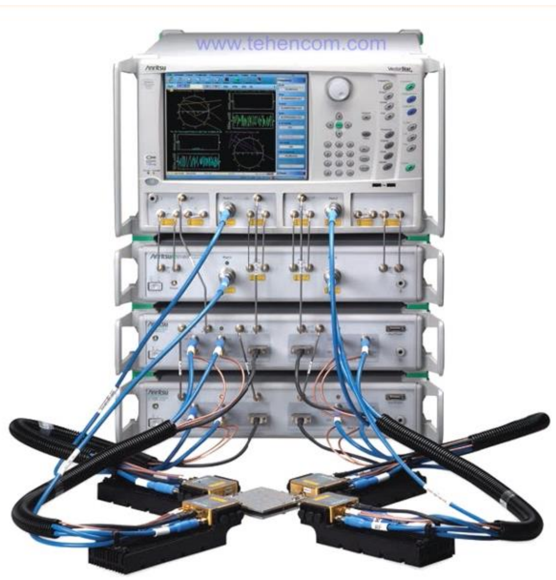

Fig. 2. – VectorStar ME7838.

Such a vector network analyzer is commonly called an N-port. As mentioned above, it is expensive, since for each of the ports it is necessary to duplicate most of the components – functional modules. The tolerance and high cost of this instrument did not justify the measurement capabilities, so two-port network analyzers were created, and then N-port switched matrix network analyzers.

Of course, a decrease in cost could affect the deterioration of the quality of some characteristics, but we will consider this in another part of the article.

Single-port VNA

We studied a one-port VNA that was designed by a group of scientists Mohamed A. Abou-Khousa, Student Member, IEEE, Mark A. Baumgartner, Sergey Kharkovsky, Senior Member, IEEE, and Reza Zoughi, Fellow, IEEE. This VNA configuration is the easiest to calibrate and use, and is significantly cheaper than other models. Figure 3 shows a block diagram of this device.

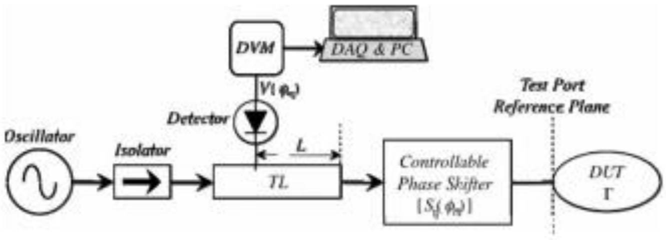

Fig. 3. – single-port VNA.

This version uses an electronically controlled phase shifter, a standing wave meter, and a device under test. The measuring device consists of a transmission line. Here it is made of a waveguide with a diode – detector. The reflected signal is bypassed with the falling signal and a standing wave is formed in the transmission line. The distance along the length of the transmission line – L creates a DC voltage that is proportional to the power of the standing wave.

Features:

The characteristics of the proposed VNA depend on:

1) detector noise level;

2) phase-shift interspacing;

3) number of phase shifts;

4) DUT reflection coefficient, i.e. low and high reflection coefficients;

5) quality of the phase shifter, i.e. return and insertion losses;

6) detector characteristics;

7) repeatability in producing phase shifts [1, p. 3].

Measurement results

We have studied the results of experiments that were done using the VNA HP8510C and the proposed analyzer. Performance graphs are shown in the figures below (Figure 4).

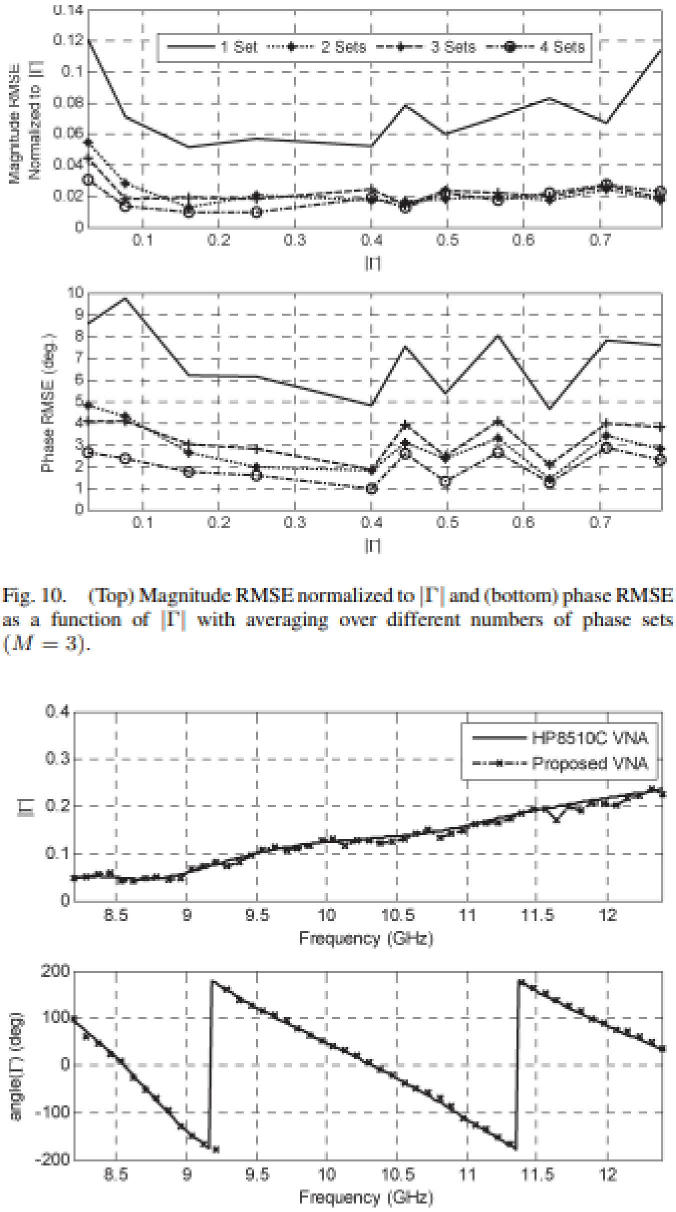

Fig. 4. – Results of the experiments.

The measurements on the proposed VNA correlate with those on the HP8510C network analyzer. This means that the proposed VNA offers reasonably accurate measurements of the complex reflectance. The coincidence of the results was up to 51 points in the measurement band without smoothing.

Also, repeated measurements of the characteristics of the phase shifter showed that they remain practically unchanged over time, which means that the proposed VNA is a reliable device.

The experiments were carried out for 5 months and all this time the characteristics of the phase shifter were quite constant. Of course, you can accurately correct for the better if you use a higher quality phase shifter, thereby reducing the insertion loss.

Conclusion

Vector network analyzers are modern and necessary equipment. As with any measuring device, the VNA has its own measurement errors. But the high cost and complexity of measurements were unjustified.

There are now many more forgiven VNA configurations with lower cost, ease of calibration, and ease of measurement.

Vector network analyzers are the future because the operating frequency range is increasing, new materials are being created that need to be investigated. All these are tasks of the VNA, which with each new step in the development of the VNA are simplified in their solution.

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